bands. Time Division Multiple Access (TDMA) systems, with at least 1 voice channel per 12.5 kHz, will be allowed and can be accommodated on adjacent 12.5 kHz channels.

At the present time, the FCC will not accept equipment for type acceptance if the equivalent channel width per voice path is greater than 12.5 kHz, and in the year 2005, that requirement is reduced to 6.25 kHz. However, the FCC does not require that 25 kHz equipment be removed from service as long as the original specifications are met. It will be shown below, that there must be incentives or regulatory mandates which form the basis for removing old equipment from the major metropolitan areas in a timely manner, or the spectrum need will be much greater than that computed in Section 9.3.1.6.

As described in Sections 7.2.1 and 7.2.2, the average voice path in 2010 will have a bandwidth projected to be 4 kHz wide. This will accommodate all voice users in the 32.3 MHz of spectrum computed in Appendix G. In this example, we continue to assume that one fourth or 25 percent of the equipment in use then will occupy a voice path bandwidth of 12.5 kHz. If, however, an additional 3.5 percent of users have 25 kHz equipment, no amount of spectrum will remain for other users, no matter how spectrally efficient (25% * 12.5/4.0 + 3.5% * 25/4=100%). If the remaining 71.5 percent of the users have an average voice path occupying only 4.0 kHz, it will require an additional 23.1 MHz of spectrum (0.715*32.3=23.1).

Therefore, it is concluded that regulatory mandates and incentives must be implemented to assure that the public safety users of wireless communications in the major metropolitan areas adopt spectrum efficient technology at an accelerated rate. Even a small number of public safety users that continue to operate equipment that is two generations old will consume the allocated bandwidth, leaving others with no means to satisfy their requirements.

9.3.2 Time Line. The net spectrum need for the state and local public safety community through the year 2010 has been developed in the document and shown to be 95 MHz. In this section, we will provide a time line which can be used to schedule the allocation of this spectrum in a timely manner.

9.3.2.1 Need by the Year 2000. In 1985, it was projected by the FCC as reported in Section 8.0.1 herein, that between 12.5 and 44.6 MHz of spectrum would be needed by the year 2000. In 1993, COPE, as reported in Section 8.0.2, requested 75 MHz for all the private services be allocated by the year 2000. Using the ratio of existing spectrum allocated of 1/3 for public safety, that results in a need of 25 MHz for the public safety community in that time frame. In Section 8.0.3, it is reported that APCO, in 1994, found that 12 MHz was needed for voice and at least 25 MHz more would be needed for advanced services by the year 2000.

Considering the range above, it is concluded from these studies that approximately 25 MHz should be allocated by the year 2000. We now turn our attention to the source for this spectrum.

9.3.2.2 Source of Spectrum for the Year 2000. At the present time, there is a move to implement Advanced Television (ATV) services in the United States. The new standard, replacing the existing National Television Systems Committee (NTSC) standard, uses a new digital modulation format. This format, and the implementation of improved TV receivers, allows the removal of the UHF TV taboos that have long required the wasteful allocation of only every sixth UHF TV channel in any individual metropolitan area. Thus, it will be possible to actually reduce the spectrum used for TV transmissions and have the same or more TV stations on the air.

It has been suggested that 24 MHz, or 4 TV channels, of a portion of the spectrum presently occupied by UHF TV channels 60-69 may be available for public safety use. The FCC is encouraged to proceed with the reallocation of this spectrum at this time, as this is directly in line with the projections of need above.

9.3.2.3 Ongoing Need After 2000. It was projected in Section 9.3.1.6 that a total of 95 MHz would be needed for public safety by the year 2010. Should 24 MHz be allocated at this time, there remains a need for an additional 71 MHz. A timely allocation of the additional need would include about half of that, or 35 MHz, prior to 2005 and the remaining portion, 36 MHz before the year 2010.

This delayed allocation plan permits the FCC to assure that the spectrum is provided for in a timely manner.

10.0 Spectrum Band Options.

10.1 Introduction. As our nation grows, the demand for public safety services also increases. Modern public safety organizations, both Federal and non-Federal, depend heavily upon wireless communications to accomplish their missions. However, radio spectrum allocated for public safety services has been fully assigned in many metropolitan areas of the United States. The allocation of spectrum for public safety use in these urban areas has not kept pace with the growth of public safety services. This spectrum shortage, if not corrected, may eventually degrade the quality of services rendered to the public.

Although there are no spectrum reserves from which to draw for public safety use, NTIA is in the process of transferring 235 MHz of spectrum (Table 10.1) to the FCC for sharing and/or reallocation. Not all of this spectrum is suitable for public safety use; however, certain of the frequency bands hold promise for advanced-technology applications.

Table 10.1

Bands Identified for Reallocation (MHz)	Reallocation Status[a]	Reallocation Schedule
1390 - 1400	Exclusive	January 1999
1427 - 1432	Exclusive	January 1999
1670 - 1675	Mixed	January 1999
1710 - 1755	Mixed	January 1999/January 2004[b]
2300 - 2310	Exclusive	Reallocation Complete
2390 - 2417	Exclusive	Reallocation Complete
2417 - 2450	Mixed	Reallocation Complete
3650 - 3700	Mixed	January 1999
4635 - 4660	Exclusive	January 1997
4660 - 4685	Exclusive	Reallocation Complete

a Some Federal stations will continue operation.

b Earlier availability date applies only to the 25 largest U.S. cities and is further subject to timely reimbursement of Federal costs, including reimbursement directly from the private sector.

The Subcommittee Working Group on spectrum band options examined the frequency spectrum from 138 MHz to 6000 MHz for applicability to public safety use, both from a technical and availability standpoint. Spectrum subject to FCC competitive bidding actions was eliminated from consideration. Spectrum above 2000 MHz was excluded from consideration for land mobile communications based upon known problems of implementation, propagation (Appendix J, Frequency Band Selection Analysis), and equipment availability. The Working Group focused on the remaining spectrum, with particular interest on current public safety spectrum, and the spectrum being transferred from NTIA.

10.2 Spectrum Band Choices

10.2.1 VHF Low Band (30 - 50 MHz). Portions of this band are currently allocated for public safety use. This band is good for wide area coverage from mobiles to dispatch centers in open terrain. Portable radios operate poorly due to antenna limitations. The band is also subject to "skip" interference between widely separated systems. Other problems with the band are high ambient noise levels, particularly on highways and near industrial areas.

Mobile relay systems are also difficult to implement. Equipment availability is an increasing problem in this band.[5]

The California Highway Patrol operates a statewide radio system in this band and in comments received[6] support migrating all public safety systems to the UHF band. Other comments from the American Association of State Highway and Transportation Officials expressed the desire to continue operating in this band. This Subcommittee recommends no new allocations be made in this band due to the band deficiencies. New spectrum is needed in the VHF and UHF bands for those agencies needing to relocate. The current public safety allocations should remain for those agencies continuing to operate in this band.

10.2.2 VHF High Band (138 to 174 MHz). There are allocations in this band for both Federal and Non-Federal public safety users. This band has good wide area mobile coverage. Comments from the State of Michigan[7] demonstrate the need to use this band for cost-effective wide-area systems. Federal agencies also require continued access to portions of this band for this very reason. For urban environments where good building penetration is a concern, this band is not as effective as higher bands (See Appendix J). The Subcommittee recommends retaining all current allocations in this band. New allocations to public safety can be made in this band by assigning the new channels from other services created by the FCC refarming proceeding. With the new Personal Communications Systems (PCS) and Enhanced Specialized Mobile Radio (ESMR) systems, there are viable alternatives for the non-public safety users to migrate to PCS and/or ESMR systems to accommodate growth requirements. Also some VHF channels allocated for the Public Mobile Service may be available for reallocation to public safety in some areas.

The 138 to 144 MHz subband is currently allocated primarily to operations by the military services. Sharing of this band with public safety is possible. Comments from the Department of Defense (DOD) indicate possible sharing with public safety on a case-by-case basis (Appendix H). Due to DOD's diverse uses of this band, a standard sharing agreement, like that used for TV sharing with land mobile, is not practical. The Subcommittee recommends that NTIA implement a standard procedure for public safety agencies to request sharing with DOD in this band.

10.2.3 VHF Television (174 to 216 MHz). This band has the same propagation characteristics as the 138 to 174 MHz band. It is an excellent candidate band for additional allocations from a technical viewpoint. Although building penetration for portables is a concern, properly designed systems can provide the necessary coverage. The main problem

5 Letters to California Highway Patrol from Ericsson and Motorola stating they will no longer manufacture equipment for this band.

6 Letter dated February 6, 1996 (PSWAC/SRS-15/1).

7 Letters dated January 23, 1996 (PSWAC/SRS-16/1) and January 25, 1996 (PSWAC/SRS-17/1).

with this band is availability for use. The broadcast industry must implement the Advanced Television (ATV) systems nationwide and phase out broadcasting in this spectrum to clear the band.[8] However, the assignments of TV channels are such that adjacent channels are not assigned in an area. Because of this, either channels 7, 9, 11, and 13 or 8, 10, and 12 are not used in an area.

This band should be considered for future public safety allocations and for immediate sharing with public safety, in the manner similar to the TV sharing in the 470 to 512 MHz band. The Subcommittee recommends that incentives to speed the clearing of this band be created by the FCC. The sharing of this band would meet needs in non-urban areas and for statewide systems. The spectrum requirements of public safety cannot be precisely known. The impact of new technologies can only be estimated at this time. This band is a good choice for reserves to meet public safety needs greater than estimated in this report. The Subcommittee recommends a portion of this band, not required for current needs, be held in reserve for a later review of public safety spectrum needs.

10.2.4 UHF (380 to 806 MHz). This band includes several sub-bands which will be discussed individually. This band has very good technical characteristics for public safety use. Many comments were received supporting the consolidation of all public safety services in this band. Although one band for public safety would be highly desirable for interoperability, the wide area coverage attributes of the VHF band are needed. This band is recommended for additional public safety voice and narrowband data allocations.

10.2.4.1 UHF (380 - 399.9 MHz). This portion of the 380 to 512 MHz band is currently allocated exclusively for military fixed, mobile, and mobile-satellite services. This band is part of a larger allocation for military operations, 225 to 328.6 MHz and 335.4-399.9 MHz. The 328.6-335.4 MHz band is allocated exclusively for the aeronautical radionavigation service. Comments received from the Office of the Assistant Secretary of Defense (OASD)[9] and the United States Coast Guard[10] strongly defend the need of this band for DOD use and Coast Guard use. Additional DOD comments concerning use of this band are contained in Appendices H and K. Use of this spectrum is critical to the national defense and supports a wide variety of uses. For example, there are over 30,000 HAVEQUICK radios that must use this spectrum to help defeat enemy jammers and other threats. Many high powered military satellites and transportable US Army radios use this spectrum. This spectrum is used in peacetime by the military to train forces. Also, during disaster relief operations (e.g., Hurricane Andrew, Los Angeles earthquake, etc.) the Air Force uses this spectrum to help coordinate the operations of cargo aircraft that must bring in relief supplies. The military also

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8 Land Mobile Spectrum Planning Options, NTIA Special Publication 95-34, October 1995. PP. 3-8 & 9.

9 OASD Comments on the PSWAC Draft Report (PSWAC/SRS-20/1), Commander Gross (OASD) briefing, April 13, 1996, at SRS meeting, and OASD letter, dated May 9, 1996 (PSWAC/SRS-21/1).

10 U.S. Coast Guard letter dated April 8, 1996 (PSWAC/SRS-22/1).

has many high-powered jammers in this spectrum to teach tactical forces how to operate under simulated enemy electronic attacks. In addition, there would be high costs associated with the reallocation of this band, resulting from the necessary redesign and reprogramming of existing military equipment.

This portion of the spectrum is desirable for use by public safety voice and narrowband data systems. No detailed investigation has been done on the use of this band segment. European public safety sharing proposals for small segments of this 20 MHz have been negotiated with the North Atlantic Treaty Organization (NATO) for use in emergencies. A similar sharing arrangement may be sought in the United States. The Subcommittee recommends discussions be initiated with the DOD and U.S. Coast Guard to ascertain the feasibility of reallocation and/or sharing.

10.2.4.2 UHF (450 - 470 MHz). This band segment is used by numerous private radio services. Reallocation of existing users to other bands would be difficult and time-consuming. There is, however, potential to reallocate the narrowband channels in other services created by the FCC's refarming proceeding. These offset channels are not licensed at this time. With the installation of new PCS and ESMR systems, there are viable alternatives for the non-public safety users to migrate to PCS and/or ESMR systems to accommodate growth requirements. Also channels allocated to the Public Mobile Service could possible be reallocated to public safety in many areas. The FCC should develop incentives to speed migration of existing users to narrowband systems (12.5 kHz channels and less) to allow rapid access by public safety users.

10.2.4.3 UHF Television (TV) Sharing (470 to 806 Mhz). Portions of this band are allocated for land mobile use in thirteen urban areas.[11] In these areas, additional allocations to public safety could be made by relocating non-public safety users to PCS or ESMR systems. This band can be used more efficiently by requiring the use of trunked systems on the same basis as the 800 MHz band. The spectrum made available in other services by the FCC refarming effort should be allocated to public safety use. The Subcommittee also recommends additional public safety allocations in this band in all areas. These allocations will need to be coordinated to clear broadcast operations as the Advanced Television service is implemented. Additional allocations on a sharing basis can be made and utilized immediately.

The TV broadcast channels 60 to 69 (746-806 MHz) have light use throughout the United States. This spectrum is adjacent to the existing land mobile use in the 800 MHz band and would be suitable for all categories of use.

Except for regulatory roadblocks, this spectrum can provide the quickest spectrum relief for frequency impacted areas.

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[11] See CFR 47 Part 90 Subpart L.

10.2.5 UHF (800 MHz Band). This band has excellent propagation properties for urban areas where building penetration is required. The band is undergoing many regulatory changes due to the Specialized Mobile Radio (SMR) allocations which are affecting all users. The FCC has distributed a docket concerning auctioning of the SMR bands and relocating existing users. Because of these changes, the Subcommittee does not recommend any new allocations in this band.

10.2.6 1990 to 2110 MHz Band. This spectrum was reallocated for emerging technologies and has not been designated for a specific use. The Subcommittee notes this band could be used by public safety for either microwave or wide band data/video use.

10.2.7 Spectrum Being Made Available By the Federal Government. These bands have been identified for sharing and/or reallocation by the Federal Government (Table 10.1). This discussion will focus on only those bands that have potential for public safety use.

10.2.7.1 (1710 to 1755 MHz). This band is scheduled for transfer to the FCC for mixed use January 1, 2004. It is suitable for wide-area wide band data and video use. The band can also be used for voice and narrowband data if required. It is in the same range as the PCS allocations and will benefit from PCS technologies. The Subcommittee recommends this as the primary band for wide band data and video (using a compressed digital format) systems. This will require equipment development by manufacturers, but equipment should be available in advance of the 2004 release date. In some areas of the country, continued Federal use is authorized. Provided proper coordination in these areas is performed between the public safety community and the existing Federal users, it should not prevent either group from meeting their critical mission requirements. The Subcommittee requests NTIA research the possibilities of sharing in this band prior to January 1, 2004, and determine the specific needs required to speed the clearing of the band.

10.2.7.2 (4635 to 4685 MHz). Although the band is not suitable for wide-area voice or data systems, it is useful for short-range mobile video systems, both compressed digital and uncompressed analog formats. This band is also suitable for point-to-point (fixed) microwave applications. The band will support low capacity (one or two T1 circuits), the capacity most needed to link remote radio sites to dispatch centers. The Subcommittee recommends this band for both the above uses.

10.2.7.3 (5850 to 5925 MHz). Although not a part of the spectrum being transferred from the Federal Government, the NTIA[12] recommends this band for Intelligent Transportation Systems (ITS) use, which has public safety-related requirements. The Subcommittee believes ITS systems should be developed in their own band allocations. However, it is anticipated that public safety and public service agencies will be able to request frequency assignments

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[12] Land Mobile Spectrum Planning Options, NTIA Special Publication 95-34. October 1995. PP. 3-8 & 9.

in this band for safety-related ITS applications. Therefore, the Subcommittee supports the NTIA recommendation.

10.3 International and Border Issues. Care must be taken to consider any international, and particularly cross-border, implications. In a number of the bands, the United States has made agreements and/or commitments with Canada, Mexico, NATO, other nations, and the International Telecommunication Union. Any of these proposed reallocations must be examined in light of these agreements. The Subcommittee recommends the FCC and NTIA consider these issues when determining the spectrum band options to meet the spectrum requirements of public safety. To aid interoperability, agreements with Canada and Mexico will be needed to resolve potential border interference issues. Immediately upon reallocation of new spectrum, discussions should be initiated with Canada and Mexico to develop appropriate Frequency Coordination Agreements.

10.4 Summary and Conclusions. There is no spectrum being held in reserve from which new allocations can be made to public safety. The bands below 2 GHz are most suitable for public safety land mobile use. To the extent possible, public safety voice systems should be consolidated into the VHF high band and UHF (380 to 512 MHz) bands. Some users in the 30 to 50 MHz band need to migrate to higher bands and will require spectrum for this migration. The 1710 to 1755 MHz band is best suited for new wide band data and video systems (new technologies). Public safety spectrum needs will come from a variety of the bands discussed in this section.

There are needs for additional spectrum for public safety fixed service (microwave) systems. The Subcommittee has not determined any suitable spectrum beyond the 4635 to 4685 MHz band. The only other option identified is to further split the 3710 to 4190 MHz band into 10 MHz bandwidth channels. More examination of the technical parameters for interference between systems should be undertaken to determine if modifications can be made to allow for more reuse of existing spectrum. The shortage of microwave spectrum will be a continuing problem for public safety microwave systems.

As there are many competing interests for spectrum, many options are presented in this section. There is an approximate 315 MHz of spectrum, not including new channels from refarming, identified to fully meet the public safety needs. The Subcommittee offers these options to the FCC and NTIA so the needs of public safety for spectrum are fully met. To assist the FCC and NTIA in the regulatory changes required, the Subcommittee recommends the following priority listing for each type of use. The Subcommittee recommends spectrum to meet the voice system needs by using spectrum at 800 MHz and below.

For voice systems, narrowband data, wide band data, and video:

1. Immediate further sharing of the 470 to 512 MHz (TV band) in all areas.
2. Reallocate all or part of the 746 to 806 MHz (TV channels 60 to 69) for public safety use.

3. Immediate allocation of the channels in other services created in the FCC's refarming proceeding at both VHF and UHF (including TV sharing bands.)
4. Eventual reallocation of all TV sharing 470 to 512 MHz channels to public safety.
5. Immediate new sharing of the VHF TV band (174-216 MHz) (primarily outside of urban areas and for statewide systems).
6. Reallocation of the 380 to 399.9 MHz band to public safety.
7. Sharing of the 380 to 399.9 MHz band with DOD on a mutually agreeable basis to minimize interference to public safety to nuisance levels.
8. Hold a portion of the 174 to 216 MHz (TV band) in reserve to meet future public safety needs or needs not met by this effort.

For wide band data and video systems:

1. Make allocations from the 1710 to 1755 MHz band.

For short range video systems:

1. Make allocations from the 4635 to 4685 MHz band.

For fixed microwave systems:

1. Make allocations in the 4635 to 4685 MHz band.
2. Make allocations in the 1990 to 2110 MHz band.

For Intelligent Transportation System:

1. Make allocations in the 5850 to 5925 MHz band.

11.0 Conclusions and Recommendations.

11.1 Conclusions.

11.1.1 State and local public safety agencies require additional spectrum to satisfy voice, data, video, and fixed service requirements, especially in major metropolitan areas. An additional 25 MHz of spectrum is needed immediately to satisfy existing voice and data requirements. A total amount of 95 MHz is required by the year 2010. The additional spectrum is required for additional voice and data use, plus use of new technologies such as wide band data and video. An additional 161 MHz of spectrum is required to meet fixed service needs.

11.1.2 The existing Federal Government spectrum allocations will satisfy Federal public safety/public service requirements through the year 2010 provided: **a) no additional spectrum is transferred to the FCC for commercial use; b) the assumed spectrum-**

efficient technologies become available; and c) funds are provided through appropriations to implement the new spectrum-efficient technologies.

11.1.3 Public safety agencies will continue to use commercial services to decrease the demands on private systems. It is estimated that commercial services will satisfy 10% of the spectrum need by 2010.

11.1.4 Additional spectrum is required for Federal, state, and local interoperability communications.

11.1.5 The implementation of Shared Federal, state, and local public safety systems will provide both fiscal and spectrum efficiencies, plus enhance interoperability requirements.

11.2 Recommendations. It is recommended an additional 25 MHz of spectrum be immediately authorized to meet existing voice, data, and video requirements. Another 35 MHz should be reallocated by 2005 and the remaining 35 MHz prior to 2010. It is recommended the following frequency bands be analyzed to determine the feasibility of authorizing public safety use.

11.2.1 Voice, Data, and Video. Some of this spectrum need can be provided by increasing the sharing of the TV spectrum in the 470-512 MHz band in all areas of the country. Other options include: a) reallocation of spectrum between 746 to 806 MHz (TV channels 60-69), b) immediate reallocation of the VHF and UHF channels in other services created by the FCC's Refarming Proceeding, c) new sharing in the 174-216 MHz TV band, and d) sharing with the military in the 380 to 399.9 MHz band.

11.2.2 Wide Band Data and Video. For Wide Band data and video requirements, reallocate the 1710 to 1755 MHz band for public safety use when it is transferred from NTIA.

11.2.3 Short-Range Video. Make allocations in the 4635 to 4685 MHz band.

11.2.4 Fixed Service. Make allocations in the 4635 to 4685 MHz, 1990 to 2110 MHz, and the 3700 to 4200 MHz bands.

11.2.5 Intelligent Transportation Systems. Make allocations in the 5850 to 5925 MHz band.

11.2.6 Interoperability Spectrum. Allocate channels below 512 MHz for Federal, state, and local public safety interoperable operations, as indicated in the Interoperability Subcommittee Report.

11.2.7 Shared Systems. It is further recommended the FCC and NTIA revise applicable frequency licensing/assignment rules to encourage sharing arrangements between Federal, state, and local agencies.

APPENDIX A

Table 5.1. Ranally Metropolitan Areas and Projected 2010 Populations (with permission from Rand McNally to use their entire table with PSWAC estimates for year 2010)

Rank	Metro and City Name	RMA	1990 Metro Pop.	Est. 1994 Metro Pop.	% Chg. Pop.	Est. 2010 Metro Pop.	Est. 1994 City Pop.	% Chg. Pop.	City Pop.	Metro Area sq mi	City Area sq mi	Metro Density Pop/sq mi	City Density Pop/sq mi
1	New York, NY-NJ-CT	N. Y.	17,310,800	17,552,300	1.4	18,522,556	7,648,300	0.7	7,915,991	6,286	333	2,947	23,772
1	A New York, NY						7,385,400	0.9	7,717,743		309		24,977
1	B Newark, NJ						262,900	-4.5	203,748		24		8,489
2	Los Angeles, CA	L.A.	11,705,000	12,253,600	4.7	14,455,675	3,495,800	0.3	3,548,237	2,595	469	5,571	7,566
3	Chicago, IL-IN-WI	CHI	7,835,300	8,096,600	3.3	9,128,125	2,762,000	-0.8	2,651,520	3,699	227	2,468	11,681
4	Philadelphia-, PA-NJ-DE-MD	PHIL-	5,529,600	5,645,300	2.1	6,110,208	1,719,500	-1.5	1,590,538	3,796	154	1,610	10,328
4	A Philadelphia, PA						1,558,400	-1.7	1,425,936		135		10,562
4	B Trenton, NJ						88,200	-0.6	85,554		8		10,694
4	C Wilmington, DE						72,900	2.0	80,190		11		7,290
5	San Francisco-, CA	SF-O	5,390,900	5,644,900	4.7	6,657,762	1,934,800	3.0	2,225,020	2,047	275	3,252	8,091
5	A San Francisco, CA						736,600	1.7	799,211		47		17,004
5	B Oakland, CA						377,600	1.5	405,920		56		7,249
5	C San Jose, CA						820,800	4.9	1,021,896		172		5,941
6	Detroit, MI-CAN	DET	4,348,100	4,401,500	1.2	4,608,986	1,106,200	-2.8	951,332	3,278	165	1,406	5,766
6	A Detroit, MI						995,700	-3.1	841,367		139		6,053
6	B Ann Arbor, MI						110,500	0.8	114,920		26		4,420
6	C incl. Windsor, CAN		4,619,100	4,679,500	1.3	4,919,342				3,611		1,362	
7	Boston, MA-NH	BOS	4,171,800	4,175,500	0.1	4,192,659	893,300	-4.0	714,640	3,106	132	1,350	5,414
7	A Boston, MA						555,500	-3.3	463,843		48		9,663
7	B Brockton, MA						87,000	-6.3	59,595		22		2,709
7	C Lowell, MA						98,100	-5.1	73,085		14		5,220
7	D Lawrence, MA						62,600	-10.8	28,796		7		4,114
7	E Haverhill, MA						52,800	2.7	59,928		33		1,816
7	F Salem, MA						37,300	-2.1	33,384		8		4,173
8	Washington, DC-MD-VA	WASH	3,808,700	4,007,800	5.2	4,798,962	574,500	-5.3	422,258	2,701	61	1,777	6,922
9	Dallas-TX	D-FW	3,606,600	3,924,800	8.8	5,193,504	1,512,900	4.0	1,815,480	2,842	623	1,827	2,914
9	A Dallas, TX						1,045,900	3.9	1,249,851		342		3,655
9	B Fort Worth, TX										281		
10	Miami-, FL	MIA	3,456,600	3,629,900	5.0	4,320,750	510,900	0.6	526,227	1,073	67	4,027	7,854
10	A Miami, FL						362,800	1.2	384,568		36		10,682
10	B Ft. Lauderdale						148,100	-0.9	141,436		31		4,562
11	Houston, TX	HOU	3,327,800	3,604,200	8.3	4,708,837	1,703,200	4.5	2,086,420	2,679	543	1,758	3,842

Rank	Metro and City Name	RMA	1990 Metro Pop.	Est. 1994 Metro Pop.	% Chg. Pop.	Est. 2010 Metro Pop.	Est. 1994 City Pop.	% Chg. Pop.	City Pop.	Metro Area sq mi	City Area sq mi	Metro Density Pop/sq mi	City Density Pop/sq mi
12	Atlanta, GA	ATL	2,621,100	2,924,600	11.6	4,141,338	403,200	2.3	449,568	3,132	132	1,322	3,406
13	Seattle-, WA	SEAT-	2,565,600	2,760,900	7.6	3,540,528	709,800	2.4	794,976	2,647	132	1,338	6,023
13	A Seattle, WA						521,300	1.0	547,365		84		6,516
13	B Tacoma, WA						188,500	6.7	251,648		48		5,243
14	Minneapolis-,MN-WI	MPLS-	2,332,100	2,470,200	5.9	3,020,070	633,900	-1.0	602,205	2,391	108	1,263	5,576
14	A Minneapolis, MN						365,500	-0.8	350,880		55		6,380
14	B St. Paul, MN						268,400	-1.4	249,612		53		4,710
15	St. Louis, MO-IL	ST.L	2,238,700	2,350,700	5.0	2,798,375	378,200	-4.7	289,323	2,267	62	1,234	4,667
16	Phoenix, AZ	PHOE	2,124,900	2,323,900	9.4	3,123,603	1,055,100	6.7	1,408,559	2,071	422	1,508	3,338
17	San Diego, CA-MEX.	SDGO	2,158,900	2,296,100	6.4	2,849,748	1,168,300	5.2	1,472,058	995	324	2,864	4,543
17	incl. Tijuana, MEX		2,893,900	3,156,100	9.1	4,210,625							
18	Cleveland, OH	CLEV	2,142,100	2,164,800	1.1	2,259,916	500,400	-1.0	475,380	1,985	77	1,138	6,174
19	Baltimore, MD	BAL	2,045,800	2,096,200	2.5	2,301,525	718,900	-2.3	636,227	1,506	81	1,528	7,855
20	Pittsburgh, PA	PGH	2,062,000	2,052,200	-0.5	2,010,450	362,300	-2.1	324,259	2,608	56	771	5,790
21	Denver, CO	DEN	1,617,900	1,775,200	9.7	2,402,582	498,000	6.5	659,850	1,267	153	1,896	4,313
22	Cincinnati, OH-KY-IN	CIN	1,547,700	1,598,100	3.3	1,803,071	363,600	-0.1	361,782	1,860	78	969	4,638
23	Portland, OR-WA	POR	1,391,700	1,519,200	9.2	2,031,882	458,400	4.8	568,416	1,379	127	1,473	4,476
24	Kansas city, MO-KS	K.C.	1,388,600	1,449,200	4.4	1,694,092	432,500	-0.6	419,525	1,842	313	920	1,340
25	Milwaukee, WI	MILW	1,407,200	1,438,400	2.2	1,561,992	620,400	-1.2	583,176	1,362	96	1,147	6,075
26	Riverside-, CA	RIV-	1,205,800	1,373,000	13.9	2,043,831	421,700	7.9	588,272	689	134	2,966	4,390
26	A Riverside, CA						242,400	7.0	327,240		78		4,195
26	B San Bernardino, CA						179,300	9.2	261,778		56		4,675
27	Sacramento, CA	SAC	1,168,100	1,272,600	8.9	1,687,905	391,600	6.0	509,080	714	96	2,364	5,303
28	San Antonio, TX	SANT	1,158,000	1,251,300	8.1	1,626,990	998,900	6.7	1,333,532	730	336	2,229	3,969
29	Indianapolis, IN	IND	1,154,500	1,219,400	5.6	1,477,760	760,700	4.0	912,840	1,620	362	912	2,522
30	New Orleans, LA	N.O.	1,147,300	1,171,600	2.1	1,267,767	494,800	-0.4	484,904	755	181	1,679	2,679
31	Columbus, OH	COL	1,085,700	1,145,800	5.5	1,384,268	649,700	2.7	737,410	1,211	192	1,143	3,841
32	Buffalo, NY-CAN	BUF	1,097,600	1,095,900	-0.2	1,086,624	317,500	-3.2	266,700	1,066	41	1,019	6,505
32	incl. St. Catherines- Niagara Falls, CAN		1,474,900	1,481,900	0.4	1,504,398				1,607		936	
33	Hartford-, CT	H-NB	1,085,900	1,082,800	-0.3	1,069,612	198,500	-7.8	121,085	1,431	30	747	4,036
33	A Hartford, CT						127,100	-9.0	69,905		17		4,112
33	B New Britain, CT						71,400	-5.4	52,122		13		4,009
34	St. Petersburg-, FL	ST.PET-	1,031,500	1,060,600	2.8	1,175,910	335,700	-0.5	327,308	397	84	2,962	3,897
34	A St. Petersburg, FL						236,600	-0.8	227,136		59		3,850
34	B Clearwater, FL						99,100	0.3	100,587		25		4,023
35	Norfolk-, VA ++	NORF-	962,300	1,024,500	6.5	1,275,048	362,400	-0.7	349,716	1,076	87	1,185	4,020
35	A Norfolk, VA						258,600	-1.0	245,670		54		4,549
35	B Portsmouth, VA						103,800	-0.1	103,281		33		3,130

Rank	Metro and City Name	RMA	1990 Metro Pop.	Est. 1994 Metro Pop.	% Chg. Pop.	Est. 2010 Metro Pop.	Est. 1994 City Pop.	% Chg. Pop.	City Pop.	Metro Area sq mi	City Area sq mi	Metro Density Pop/sq mi	City Density Pop/sq mi
36	Memphis, TN-AR-MS	MEM	951,500	995,700	4.6	1,170,345	626,700	2.7	711,305	1,272	263	920	2,705
37	Orlando, FL	ORL	900,400	988,500	9.8	1,341,596	181,000	9.9	270,595	629	70	2,133	3,866
38	Providence-, RI-MA	PROV-	979,300	983,900	0.5	1,003,783	240,000	-2.5	210,000	908	55	1,105	3,818
38	A Providence, RI						153,700	-4.4	119,886		19		6,310
38	B Warwick, RI						86,300	1.1	91,047		36		2,529
39	Louisville, KY-IN	LOU	887,600	911,300	2.7	1,007,426	271,800	1.0	285,390	996	62	1,011	4,603
40	Oklahoma City, OK	O. C.	850,900	886,800	4.2	1,029,589	457,800	2.9	524,181	1,426	608	722	862
41	Las Vegas, NV	LASV	720,900	882,500	22.4	1,528,308	317,900	23.1	685,075	515	85	2,968	8,060
42	Honolulu, HI	HON	836,200	876,500	4.8	1,036,888	373,200	2.2	414,252	600	83	1,728	4,991
43	Salt Lake City , UT	S.L.C.	801,000	872,300	8.9	1,157,445	169,700	6.1	221,459	418	109	2,769	2,032
44	Rochester, NY	ROCH	838,000	851,200	1.6	905,040	233,300	0.7	241,466	1,390	36	651	6,707
45	Jacksonville, FL	JAX	777,100	829,300	6.7	1,037,429	673,600	6.0	875,680	963	759	1,077	1,154
46	Richmond, VA	RICH	785,300	825,100	5.1	985,552	200,700	-1.2	188,658	1,030	60	957	3,144
47	Tampa, FL	TAM	780,500	819,400	5.0	975,625	287,900	2.8	328,206	591	109	1,651	3,011
48	Dayton, OH	DAY	780,000	800,600	2.6	881,400	185,000	1.6	199,800	1,100	56	801	3,568
49	Nashville, TN	NASH	749,500	793,100	5.8	966,855	502,800	2.9	575,706	1,464	398	660	1,446
50	Albany, NY	A-S-T	756,200	772,800	2.2	839,382	218,300	-1.2	205,202	1,357	42	619	4,886
50	A Albany, NY						99,300	-1.8	90,363		21		4,303
50	B Schenectady, NY						65,200	-6.0	45,640		11		4,149
50	C Troy, NY						53,800	-9.0	29,590		10		2,959
51	Birmingham, AL	BIR	722,700	742,800	2.8	823,878	264,700	-0.5	258,083	1,180	149	698	1,732
52	Austin, TX	AUS	631,100	701,800	11.2	984,516	518,300	11.3	811,140	510	220	1,930	3,687
53	Akron, OH	AKR	666,400	685,300	2.8	759,696	223,700	0.3	227,056	825	63	921	3,604
54	Charlotte , NC-SC	CHRLT	598,400	659,000	10.1	900,592	462,700	16.9	853,682	984	194	915	4,400
55	Tucson, AZ	TUC	608,200	659,000	8.4	863,644	435,400	7.4	596,498	778	159	1,110	3,752
56	El Paso, TX-NM-MEX	ELP	592,100	653,000	10.3	897,032	561,700	9.0	814,465	377	245	2,379	3,324
56	Ciudad Juarez, MEX.		1,387,100	1,563,000	13.5	2,323,393				437		5,317	
57	Tulsa, OK	TUL	615,600	646,200	5.0	769,500	379,300	3.3	441,885	1,089	184	707	2,402
58	Knoxville, TN	KNOX	600,800	629,100	4.7	741,988	167,600	1.5	180,170	1,802	84	412	2,145
59	Toledo, OH-MI	TOL	591,700	600,100	1.4	633,119	331,600	-0.4	324,968	942	81	672	4,012
60	Grand Rapids, MI	GDR	570,200	598,300	4.9	709,899	193,800	2.4	217,056	1,058	44	671	4,933
61	Albuquerque, NM	ALBU	542,800	595,000	9.6	803,344	416,500	8.3	589,348	477	134	1,684	4,398
62	Omaha, NE-IA	OMA	571,100	594,600	4.1	688,176	345,100	2.8	393,414	446	103	1,543	3,820
63	Allentown- PA-NJ	AL-B	559,700	575,000	2.7	635,260	181,700	2.9	208,047	790	37	804	5,623
63	A Allentown, PA						108,000	2.8	123,120		18		6,840
63	B Bethlehem, PA						73,700	3.2	85,492		19		4,500
64	Fresno, CA	FRES	515,000	573,500	11.4	808,550	397,400	12.2	639,814	456	99	1,773	6,463
65	West Palm Beach, FL	WPB	488,400	536,200	9.8	727,716	69,300	2.5	77,963	337	53	2,159	1,471
66	Syracuse, NY	SYR	529,500	535,800	1.2	561,270	160,800	-1.9	145,524	1,084	25	518	5,821

APPENDIX B

The Role Of

Commercial Wireless Services

And Their Impact On Spectrum Requirements

Submitted by Motorola Inc. to the

Public Safety Wireless Advisory Committee

Wednesday, May 29, 1996

In an appearance before the US Senate Committee on Commerce, Science and Transportation, PSWAC Chair Phil Verveer stated that "Commercial mobile radio services can absorb some of public safety's demands." We agree with this general statement and believe it is consistent with the sentiment of the majority of the PSWAC committee. To help clarify the salient issues on this topic, this paper will expand upon this statement and offer a clear opinion of the extent to which public safety demands that "can" be absorbed by commercial mobile radio service *would* be absorbed and identified and size "some of public safety's demands" that would be absorbed.

Commercial wireless services cannot be widely used to replace an entire public safety private system, or even a significant portion of one, because most public safety communications cannot be adequately served by commercial mobile radio services today or in the foreseeable future. Public safety requires a level of customized service that significantly exceeds, or is at least distinctly different than, that which is demanded by the principal users of commercial wireless services — business/industrial users and individual consumers. Since commercial mobile radio services are fundamentally designed to meet the more modest needs of private sector customers and individual consumers they do not offer the type or level of service demanded by public safety. Also, it is unknown whether the providers of commercial wireless services would make the significant investment in improvements that would be required to adequately serve public safety.

For the public safety user, the major deficiencies of commercial wireless services center around their general inability to provide instant push-to-talk group dispatch, guaranteed access, priority access, security and remote location coverage. A public safety user operating over a wide area may have a communications footprint that would require piecing together service from multiple providers to form a commercial wireless "system" that meets their coverage requirements. Additionally, the multiple commercial wireless service providers may be using different technologies that are not interoperable with each other.

Public safety organizations engage in a wide variety of activities in their mission to protect life, property, and provide for the public safety. Like any other public or private sector organization, their activities range from those that are mission-critical and primary to the core activities of the organization to those that are of a more subordinate nature and therefore of a lower priority. The communications needed to support these activities are similarly wide ranging and carry differing operational requirements. The gap between what is required by public safety and what can be delivered by commercial wireless services is widest among mission-critical communications and narrowest among lower priority communications.

Public safety private systems are primarily designed to handle the higher priority mission-critical communications. A properly designed private system is designed to accommodate all mission-critical communications during peak load time periods. Any system designed for peak load capacity will, by definition, have excess capacity during off peak time periods.

Since the gap between what is required by public safety and what can be delivered by commercial wireless services is narrowest for lower priority communications, these applications are the strongest candidates for placement on commercial wireless services. However, if lower priority communications are retained on the private system the users can leverage their infrastructure investment and fill available system capacity. Lower priority communications can coexist on a private system designed for peak load mission-critical communications because the system manager has the ability to manage radio traffic to ensure that mission-critical communications get through during peak load periods while lower priority communications are postponed until capacity is available.

The protocol for managing communications traffic can be either technology-based or policy-based. Trunked systems provide a technology-based solution whereas conventional systems must rely on policy-based solutions. Trunked system priority access capabilities that can be used to assign priority to members of the system. These priority assignments can be used to queue channel requests and even displace low priority communications that are in process with high priority mission critical communications. Conventional systems cannot assign priority but can incorporate unit identification to allow monitoring of channel usage to ensure that priority based policies and procedures are followed by all users during peak load periods.

CONCLUSIONS

Mission-critical communications can not be adequately served by commercial wireless services. Therefore, it is in the public interest for the FCC to allocate sufficient spectrum to allow public safety to design and build private systems that can handle all mission-critical communications during peak load time periods.

Many lower priority communications can be served by commercial wireless services. Therefore, the FCC should weigh the macro economic factor of alternative spectrum use when considering the prospect of allocating private spectrum for these types of communications by public safety agencies. The FCC should not allocate additional private spectrum to public safety for low priority communications that can be adequately provided for by commercial wireless services.

Public safety should be allowed to choose whether low priority communications should be placed on commercial wireless services or remain on their private system. The budget pressures felt by public safety agencies are expected to continue through the time period under consideration here. Any opportunity to save money with a solution, private or commercial, that meets their requirements would be eagerly embraced. Decision makers at the state or local level are in the best position to weigh the economic and market factors affecting their situation and decide where to place their lower priority communications.

In public safety today, commercial wireless telephone interconnect and paging are widely used, primarily for connectivity with individuals or organizations outside the private system. This usage will continue into the future and it is widely believed to increase significantly. However, this wide spread supplemental or complementary usage is actually irrelevant to the determination of spectrum needs for public safety. It represents a usage that the planners of public safety systems have already identified as being outside the scope of their private system and was never intended to be included in PSWAC's quantification of incremental spectrum needs for public safety.

As we've discussed, the communications requirements of mission critical and lower priority communications are primarily differentiated by the extent to which guaranteed priority system access and security are required. One way to forecast the amount of public safety spectrum that would be absorbed by commercial wireless services would be to estimate the amount of lower priority communications and then estimate the amount of that which public safety private system planners would choose to have coexist , on a secondary basis, with mission-critical communications on the private system instead of moving them to commercial wireless services.

We believe that mission critical communications represent the majority of communications on a private system. We also believe that a majority of the lower priority communications can be retained, if desired, on a private system which is designed for mission critical peak loads by employing priority protocols that allow unrestricted lower priority communications during off peak periods but limits or eliminates them during peak periods. If we assume that mission critical communications represent two-thirds to three-fourths of all communications and that private systems can retain two-thirds to three fourths of lower priority communications, the percentage of all public safety communication that would move to commercial wireless service would be on the order of 6-11%.

It is difficult to accurately forecast commercial wireless service usage because it is difficult predict the extent to which the providers of commercial wireless service will make the necessary and significant investments to further serve public safety. Even if long range strategic plans for public safety were being developed by some commercial wireless service providers, it would be unrealistic to expect them to jeopardize their business position by prematurely revealing their plans in order to aid PSWAC. Nevertheless, we believe the 6-11% percent range is of the right order of magnitude.

In his appearance before the US Senate Committee on Commerce, Science and Transportation, Mr. Verveer also stated that "...the advisory committee will attempt to factor the CMRS alternatives into its conclusion about the amount of additional spectrum public safety requires". Motorola recommends that after the advisory committee has concluded the amount of additional spectrum required by public safety it use a factor of 10% to reduce that amount to reflect the impact of commercial wireless services.

APPENDIX C

PUBLIC SAFETY WIRELESS ADVISORY COMMITTEE MODEL FOR PREDICTION OF SPECTRUM NEED THROUGH THE YEAR 2010

A WHITE PAPER

MOTOROLA **DRAFT v1.1** **February 2, 1996**

EXECUTIVE SUMMARY

The present service requirements of the public safety community that relate to wireless communications have been identified and projected through the year 2010. Future service requirements have also been identified that are made possible by advances in semiconductor and computer technology that will add to the efficiency and safety of public safety officers as well as the communities which they serve. All of these service requirements include voice, data, image and video. For each of these, the average number, duration, and message load offered, as they relate to the use of wireless communications now and in the future, have been quantified.

The technological parameters that relate the service requirements to spectrum need include RF transmission rate, digital coding, channel occupancy, and error control. The historical rate of change in these have been determined, and then projections were made into the future. A geographical model of Los Angeles which contained 390 thousand public safety officers with advanced services radios was then identified as shown below. The spectrum need for each was also determined as shown, and this is the basis that shows that 84 MHz of RF spectral bandwidth should be provided for public safety applications through the year 2010.

Spectrum Requirements 1996 through 2010		
SERVICE	**THOUSANDS OF USERS**	**SPECTRUM BANDWIDTH MHZ**
VOICE	273	20
TRANSACTION PROCESSING	195	5
FACSIMILE	117	9
SNAPSHOT	156	19
DECISION PROCESSING/ REMOTE FILE TRANSFER	117	14
SLOW VIDEO	27	6
FULL MOTION VIDEO	3	9
COMPUTATION TOLERANCE	NA	2
TOTAL		84

I. INTRODUCTION

The goal of the Public Safety Wireless Advisory Committee is primarily to advise the FCC and NTIA on the "operational, technical, and spectrum requirements of federal, state, and local public safety entities through the year 2010."[1] The objective is to bring about significant enhancement to the effectiveness and efficiency of public safety communications. Wireless communications have been well used by public safety in the past, and with proper planning, even better use can be made in the future.

This paper will examine the implications of semiconductor advances on computing and telecommunications, and the wireless offering of related services that will impact the public safety community.[2] The present state of semiconductor technology is reviewed in Appendix A, and the cost impact on one market is illustrated. The operational requirements of public safety will be reviewed and projected through the year 2010.

It is the function of this paper to present the best intellectually supportable forecast for the spectrum needed by public safety by 2010. A model will be used that is based on a projection of the current state of digital compression and wireless radio delivery technologies that apply to public safety needs. From that, a forecast is made for the amount of spectrum which will be needed for specific advanced telecommunication services through the year 2010.

II. SPECTRUM PREDICTION MODEL

We are herein proposing an engineering methodology for projecting spectrum needs. We will show a methodical approach to projecting the trends of key technologies, and how that approach can be employed to predict future spectrum requirements. The relationships between need and required spectrum can be described in terms of technical parameters. Mathematical equations can then be used to project the bandwidth of spectrum required. This methodology has been previously employed in the COPE[3] petition, and we use this as a starting point. The steps to be used are:

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1 FCC/NTIA Report No WT 95-22, Wireless Telecom Action, September 8, 1995.

2 This paper draws heavily from a paper by Allen Davidson and Larry Marturano titled Impact of digital techniques on future LM spectrum requirements, IEEE Vehicular Technology Society News, May, 1993. New material given in this paper and some material deemed of importance will be referenced herein. The reader is referred to the predecessor paper for complete citations.

3 Coalition of Private Users of Emerging Multimedia Technologies (COPE), FCC Petition for Rule Making, Spectrum Allocations for Advanced Private Land Mobile Communications Services, filed 12/23/93. COPE represents many private users of land mobile radio, including public safety organizations such as the Association of Public Safety Communications Officials, International (APCO) and the Public Safety Communications Council (PSCC).

1) Identify the geographical area over which the model will be applied and the population of officers who will use the services to which the model applies. We will use the greater Los Angles area herein.

2) Identify the advanced services that will be used by the public safety community through the year 2010.

3) Identify a self consistent set of technical parameters that can relate the usage of the advanced services to the spectrum required in a spectrally efficient manner.

4) Quantify those technical parameters for each of the advanced services.

5) Compute the spectrum need for each of the advanced services and sum them to obtain the total spectral need for public safety through the year 2010.

Each of these will be discussed in turn in the sections to follow. The application of semiconductor technology to radio communications has resulted in certain technology trends that can be useful in these discussions. Several of these trends are presented in Appendix B.

A. Metropolitan Area and Population (POP)

Above we identified the greater metropolitan area of LA as the area which will be used for the computation.[4] The population of public safety users there has been evaluated by the Association of Public Safety Communications Officials (APCO).[5] They show that there were an estimated 78,000 mobile and portable radios in the Los Angeles area in the year 1985, and that this number was estimated to grow to 155,000 by the year 2000.

However, the actual growth in the number of licensed mobile and portable radios in the public safety service between 1985 and 1990 as published by the FCC was much greater than had been estimated in 1985. The actual growth rate by the year 1990, 11.6 percent, produced 135,000 mobiles and portables. Using a much more conservative growth rate of 6.0 percent from 1990 to 2000 and 5.0 percent from 2000 to 2010 they projected that the population of public safety units will be 390,000 by the year 2010.

We will use this estimate as the population for our computation herein; it will be abbreviated POP in the equations to follow. This number may appear to be somewhat large for the population of resident public safety officers in the greater metropolitan area of Los Angeles. However, when one considers the case of a large emergency, where virtually all of the normal activities continue, and there is a large influx of additional resources which must interpolate with the resident population, the number seems very reasonable.

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4 It would have been possible to use the areas around New York or Chicago as these are crowded users of the spectrum and would also have provided a valid result.

5 The impact of Advanced Technologies on Public Safety Spectrum Requirements, prepared by APCO Spectrum Needs Task Force, July 1994

B. Advanced Services

The advanced services which will be available to the public safety community by the year 2010 are:

Table 1
Advanced Services

- voice dispatch (to support other services)
- telephone interconnect
- transaction processing
- facsimile
- snapshot
- decision processing/remote file access
- slow video
- full motion video

Each of these are described in detail in Appendix C and will not be described further here. The land line services that are driving the need for these advanced services in the public safety environment are also described in Appendix C. Further, some examples are given there of the first steps being taken to bring them into the wireless world.

C. Technical Parameters

A set of parameters that apply to the model at hand are given below, and each of them will be described further in the paragraphs to follow.

Table 2
Parameters Used in Model

- penetration of each service into the target population (%)
- source content (kbytes or kbits/sec)
- expected coding improvement (factor)
- average duration of message (sec)
- calls per hour (number)
- RF transmission rate (bits/sec/Hz)
- error control (% of transmission)
- average busy hour channel loading factor (related to blocking, %)
- geographic reuse factor (factor)

1. Service Penetration Into Target Population (PEN)

The penetration of each of the services into the population of public safety users is represented by the shortened form PEN in the equations to follow. It is a dimensionless quantity that may be expressed as a percentage, and as the penetration into any service increases, the amount of spectrum needed will also increase.

Each of the above identified services will not be used by all of the population of 390 thousand users of the advanced services identified above. For example, transaction processing functions will probably be used frequently by a traffic officers as they request data on license numbers. But they will probably not use telephone interconnect in their regular duties. An officer on foot may frequently receive mug shots of individuals who are wanted for some reason. But they will not usually need to transmit or receive long files such as locations of gas lines or power lines such as a firefighter is interested in.

The estimation of the penetration should also take into account that out of the ordinary emergencies require services that may not be used on an every day basis. Thus, adequate penetration should provide for the unusual. The penetration that will be used in the sample computation to follow is given in Table 3.

Table 3
Penetration of Services Into the User Population

SERVICE	PENETRATION, %
Voice	50
Transaction Processing	50
FAX	30
Snapshot	40
Remote File Access	30
Slow Video	7
Full Motion Video	0.7

2. Source Content (SRC)

The content of the source message to be transmitted is represented by the shortened form SRS in the equations to follow. It is given in two forms, depending on the service being discussed. Those services which have a stringent latency requirement, which include voice, telephone interconnect, slow video, and full motion video, are expressed in bits per second.

The data services which include transaction processing, snapshot, facsimile and decision processing are given in kbytes. In order to determine the number of bits per second required of these services, we multiply by 8 to determine the number of bits, and then divide by the average duration of the message which is described in 5 below.

The magnitude of the source content is that content which is contained in the state of the art message today, including any coding improvement that has been done. Advances in coding are addressed in the next parameter. The content of the advanced features is discussed in Appendix C, and are summarized in Table 4.

3. Coding Improvement (COD)

The coding improvement is a dimensionless factor that describes the anticipated improvement in coding that will take place between the years 1996 and the year 2010. The shortened term

COD is used in the equations to follow. This too is described in Appendix C and in Table 4 below.

Table 4
Source Content, Compression Ratio, and Future Content

ADVANCED SERVICE	CONTENT	IMPROVEMENT	FUTURE SOURCE CONTENT
Decision Processing/ Remote File Transfer	200 kbyte	2 to 1	100 kbyte
4 Page FAX	92 kbyte	3 to 1	31 kbyte*
SNAPSHOT, including			
Fingerprint Inbound	3 kbyte	1 to 1	3 kbyte
Fingerprint Outbound	6.25 kbyte	1 to 1	6.25 kbyte
Mug Shot Outbound	2.5 kbyte	1 to 1	2.5 kbyte
EMS Picture	103 kbyte	2 to 1	51 kbyte
Slow Video	384 kbps	3 to 1	128 kbps
Full Motion Video	1.5 kbps	3 to 1	500 kbps

4. Duration of Message (DUR)

The needs of each mobile officer who uses the services in question will now be predicted. The length, or duration, of the messages on the RF link will be called the DUR in the equations to follow.

Table 5 summarizes the number of seconds that each transmission will take on average. In the case of voice dispatch, the length of the message on private trunked systems averages about 24 seconds and on community repeaters it averages about 17 seconds.[6] On public safety systems the length us frequently less because of the strict discipline enforced on those systems. Telephone interconnect calls are usually much longer, and in the public safety environment, where there may be a hostage situation, the length can become hours. However, the average call length for the composite voice application which is used in conjunction with the advanced services is taken as 24 seconds.

6 Garry C. Hess, Land-Mobile Radio System Engineering, Artech House, Boston - London, 1993, pp.249-253.